GPFS Overview

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Topics

PART I:

- General GPFS Architecture and Functionality
  - Highlights
  - GPFS Model
  - VSD Configuration
  - Structure
  - Data Flow

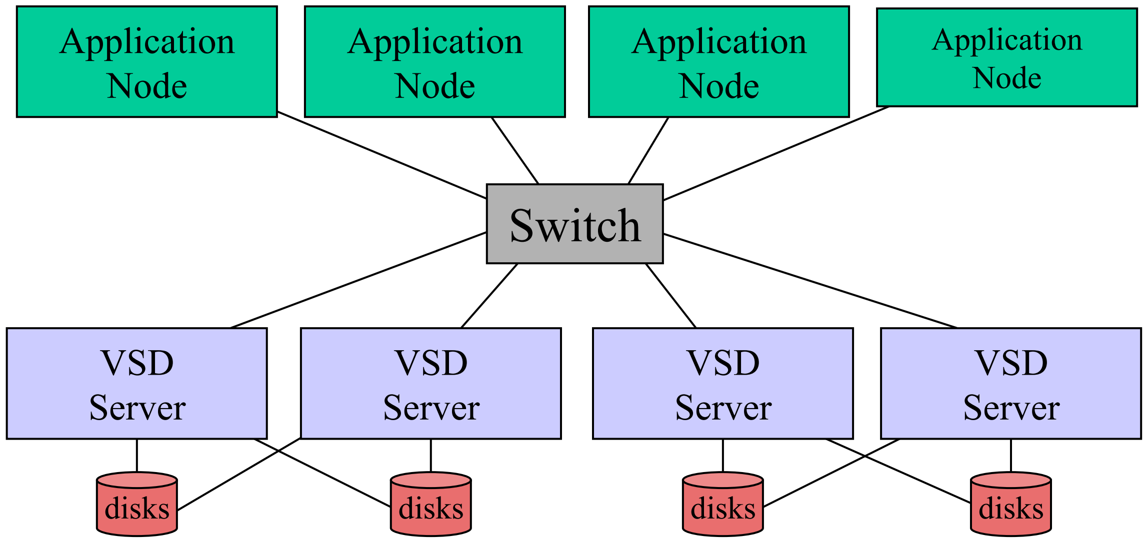
PART II:

- GPFS on Linux
- Operation/Security
- Comparison against other file systems
- Sysadm view
- Performance

GPFS Highlights

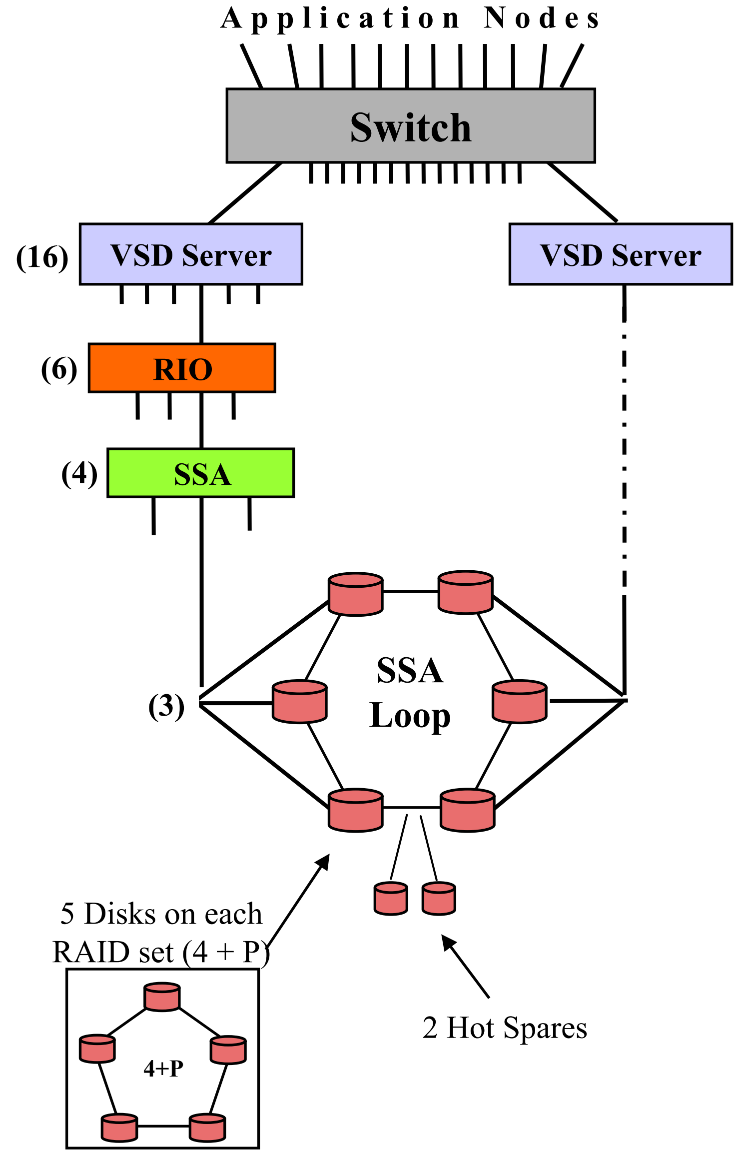
- scalable – allows incremental improvements by adding hardware
- global access – uniform access to file system from every node
- distributed locking – allows for parallelism and consistency
- portable – provides POSIX interface to file system
- reliable – offers recovery mechanisms, including
  - high availability – file system will remain accessible to nodes even when a node in the file system dies
  - fault tolerance – file data will not be lost even if some disk in the file system fails

GPFS Model


Application Node
Application Node
Application Node
Application Node
Switch
VSD Server
VSD Server
VSD Server
VSD Server
disks
disks
disks
disks

Hardware

(as configured on white)

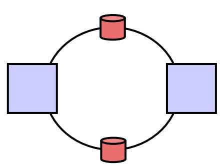


• application node – node running user app that accesses mounted GPFS

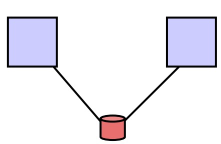
• VSD server node – *Virtual Shared Disk* node (or I/O node) with disks attached

• RIO – *Remote I/O* that allows for a connection between the server node and the disks

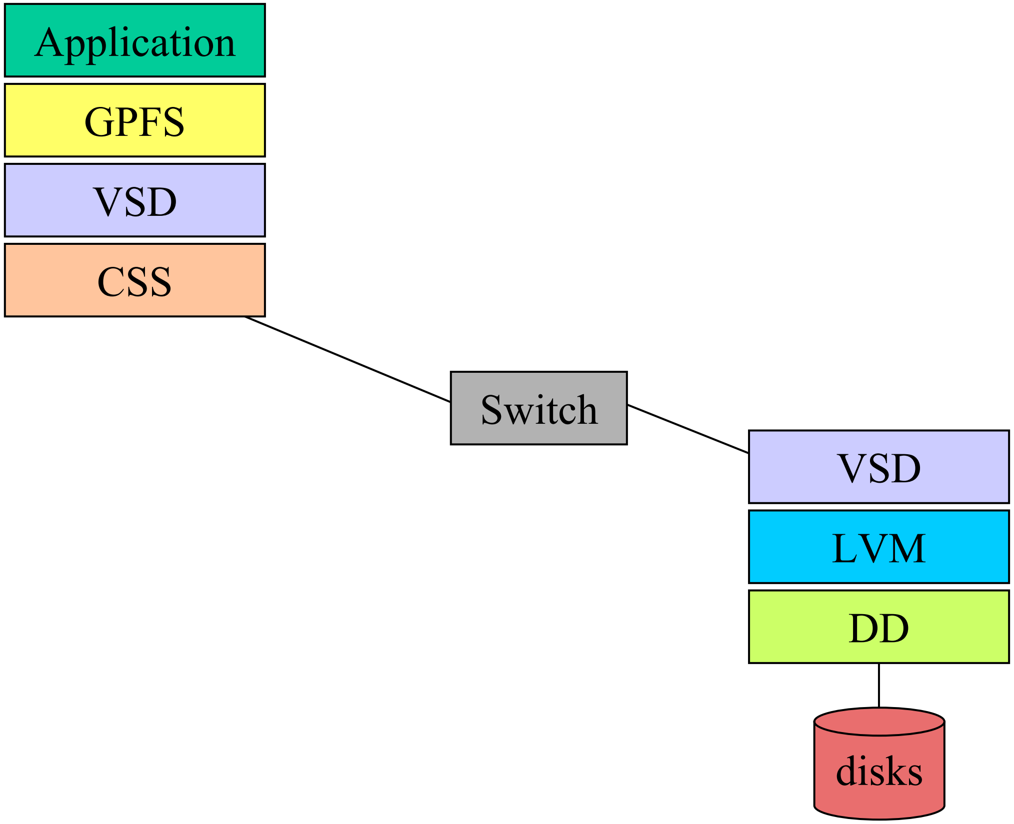
• SSA loop – *Serial Storage Architecture* disks may be connected in a loop between nodes, allowing for failover:



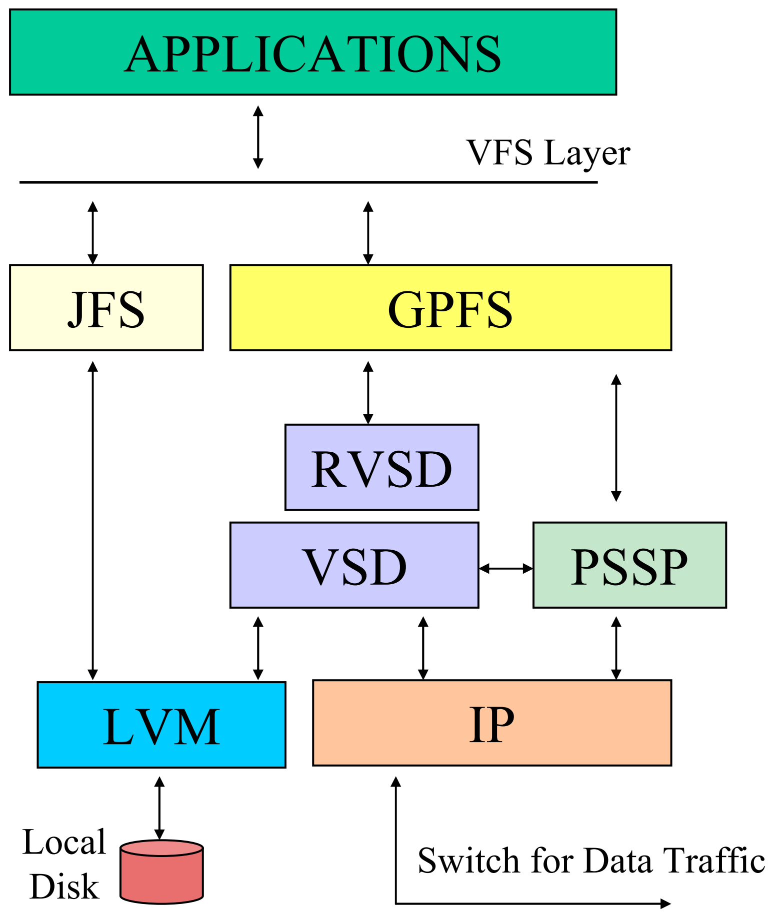
(This is in contrast to a twin-tailed approach which is used for SCSI [*Small Computer System Interface*]disks to connect two nodes to a single disk.)



Simple Configuration



More detailed Configuration



General GPFS Structure

- GPFS resides on each node as a multi-threaded daemon (called *mmfsd*) and a kernel extension.
- The daemon provides data and metadata management, such as disk space allocation, data access, I/O operations, security, and quota managements.
- The kernel extensions are needed to implement the Virtual File System (VFS) layer to present GPFS as a local file system to an application.
- To access to the data disks comprising the file system, each node uses VSD/RVSD (*Virtual Shared Disk* and *Recoverable Virtual Shared Disk*).
- VSD enables nodes to share disks (a logical volume that can be accessed by any node in the system partition.) VSD is comprised of a server/client relationship.

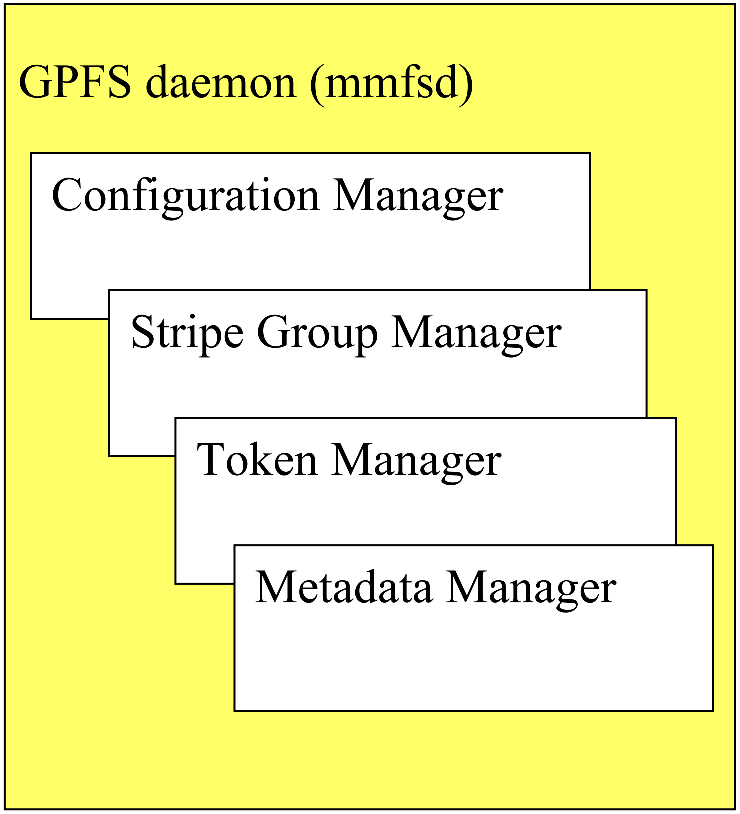
The mmfsd daemon performs all of the I/O and buffer management, including:

- allocation of disk space
- metadata management
- initiation of disk I/O
- implementation of security and quotas
- read-ahead (prefetch) caching – analyzes read pattern and reads more data
- write-behind caching – buffers data until collects efficient write size
- token management – allocation of locks for data and metadata management

The daemon implements these global management functions through several managers.

GPFS Structure

- mmfsd daemon
- Global Mgt. Functions
  - Configuration Manager
  - Stripe Group Manager
  - Token Manager Server
  - Metadata Manager



Global Management Functions

These main management functions may be performed by a single node on behalf of all the other nodes, however it is possible to have these tasks performed by different daemons on different nodes.

Configuration Manager: (single daemon in the pool of nodes performs this role)

- can determine *quorum* (minimum number of nodes in nodeset to start)
- provides *fencing* of a failed node if necessary for continued operation
- if Configuration Manager crashes, another node will run an instance (it's recoverable)

Global Management Functions

Stripe Group Manager: (single daemon in the pool performs this per file system) (also called the File System Manager)

- a ‘Stripe Group’ is a collection of disks that make up physical storage
- file system configuration – adding disks, file system repair, etc.
- disk space allocation management – handles data blocks and inode mapping, and controls which disk regions are allocated to each node (allowing for effective parallelization)
- token management – sends token requests to Token Manager Server
- mounting/unmounting of file system
- quota management
- security services

Global Management Functions

Token Manager Server: (single daemon performs this on the Stripe Group Mgr node, i.e., the entire file system)

The status of the token is held by both the Token Manager Server and the Token Manager (a kernel extension on the requesting node).

- file is local (served by this node) – a token is granted by the local Token Manager and then informs the Token Manager Server of the request.
- file is remote (served by another node) – the Token Manager requests the token from the Token Manager Server.

GPFS offers:

- byte-range locking – tasks are granted exclusive access to portions of file, allowing parallel applications to access non-overlapping blocks of a file with minimal contention
- file locking – entire file is locked by single task

Global Management Functions

Metadata Manager:

- metanode – for each open file, a single node is responsible for updating that file's metadata. This node changes if another node gains access to the file.

File Structure

- Allocation
  - A standard i-node (*index*-node) structure is used for file allocation. The i-node contains attributes of the file (size, owner, permissions, dates, pointer to data or indirect block, etc.) plus the pointer (direct or indirect) to the data blocks.

  - The number of i-nodes is statically set at file system creation time and may not be altered.

File Structure

- Striping
  - Each file system consists of a set of VSD disks constituting a *stripe group*. The purpose of striping is to improve I/O performance by allowing records to be subdivided and simultaneously written to multiple disks. Since this happens without user explicit involvement, it is called *implicit parallelism*.

  - RAID strip width should (but might not!) match the block size of the file system. These are two different parameters.

File Structure

- Blocks can be striped in three ways:
  - round robin – randomly select first disk, then continue writing blocks to successive disks
  - random – randomly select disk for each block
  - balanced random – used when disks are not same size, randomly distributing blocks to disks in a manner proportional to their size; also described as round robin, but does not select a disk in the stripe group again until all disks have been used

File Structure

- Metadata
  - Used to locate and organize user data contained in GPFS's striped blocks. I-nodes contain direct pointers to user data or indirect pointer to indirect blocks. Indirect blocks may point to other indirect blocks or to user data blocks. In GPFS 1.4, a maximum of two levels of indirection is allowed.

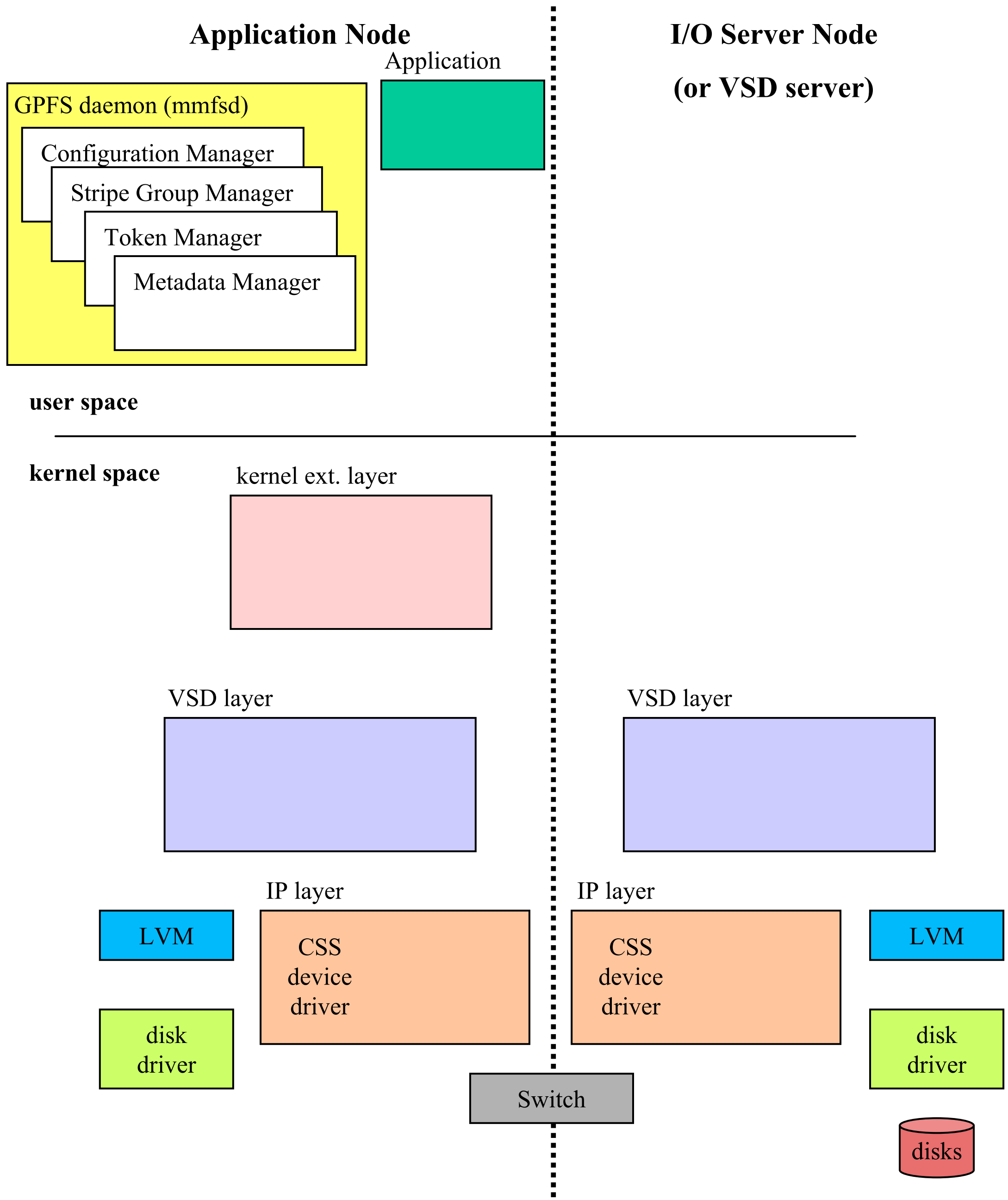
File Structure

- File Size (in GPFS 1.5)
  - 4 petabytes per file system
  - 2^{63}-1 bytes (~8 exabytes)
  - 256 million files per file system (limit in GPFS 1.4 and GPFS for Linux 1.1)

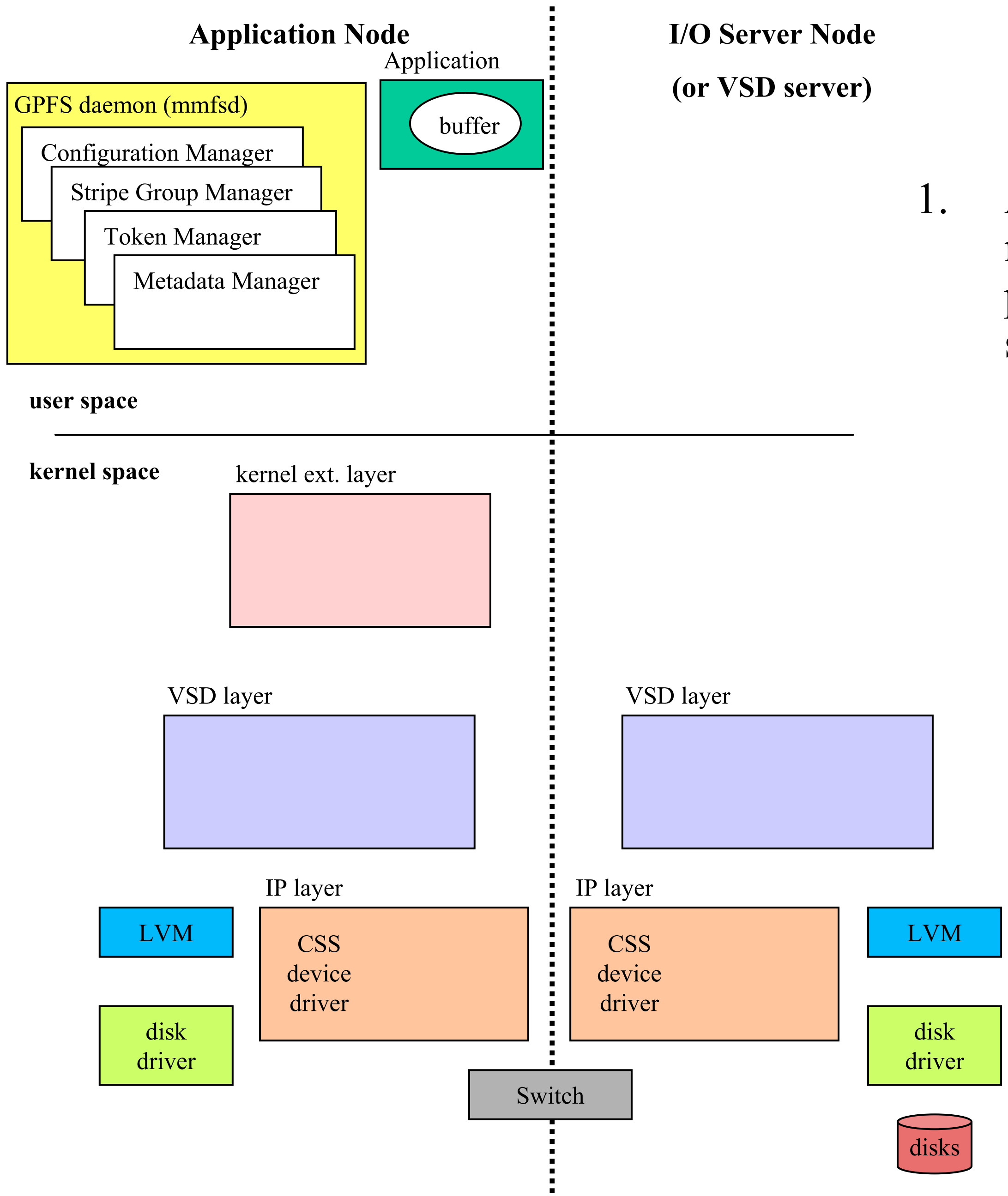
Memory Utilization (GPFS Cache)

- The *page pool* is the GPFS cache of dedicated and pinned memory. (Pinned memory is memory that can not be swapped, used to increase performance.)
- The page pool allows for client-side caching, which offers a performance gain by not having to transfer data to/from disk and across the switch.
- The size of the page pool is an upper limit of the actual size of the page pool on each node. GPFS dynamically adjusts the amount necessary for the page pool to the max setting. The range is 4MB – 512MB in GPFS 1.4

DATA FLOW MODEL

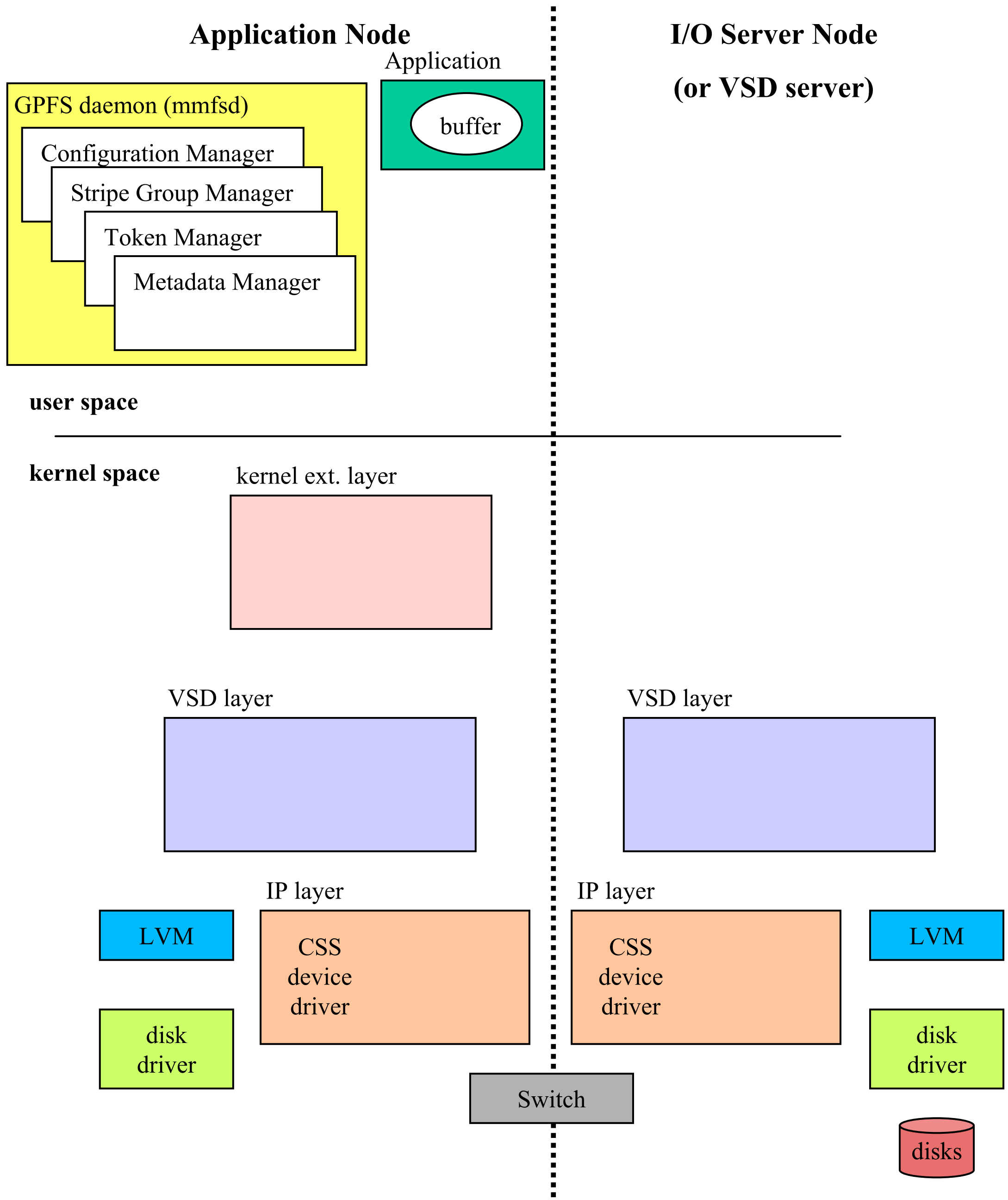


Data Flow (write)



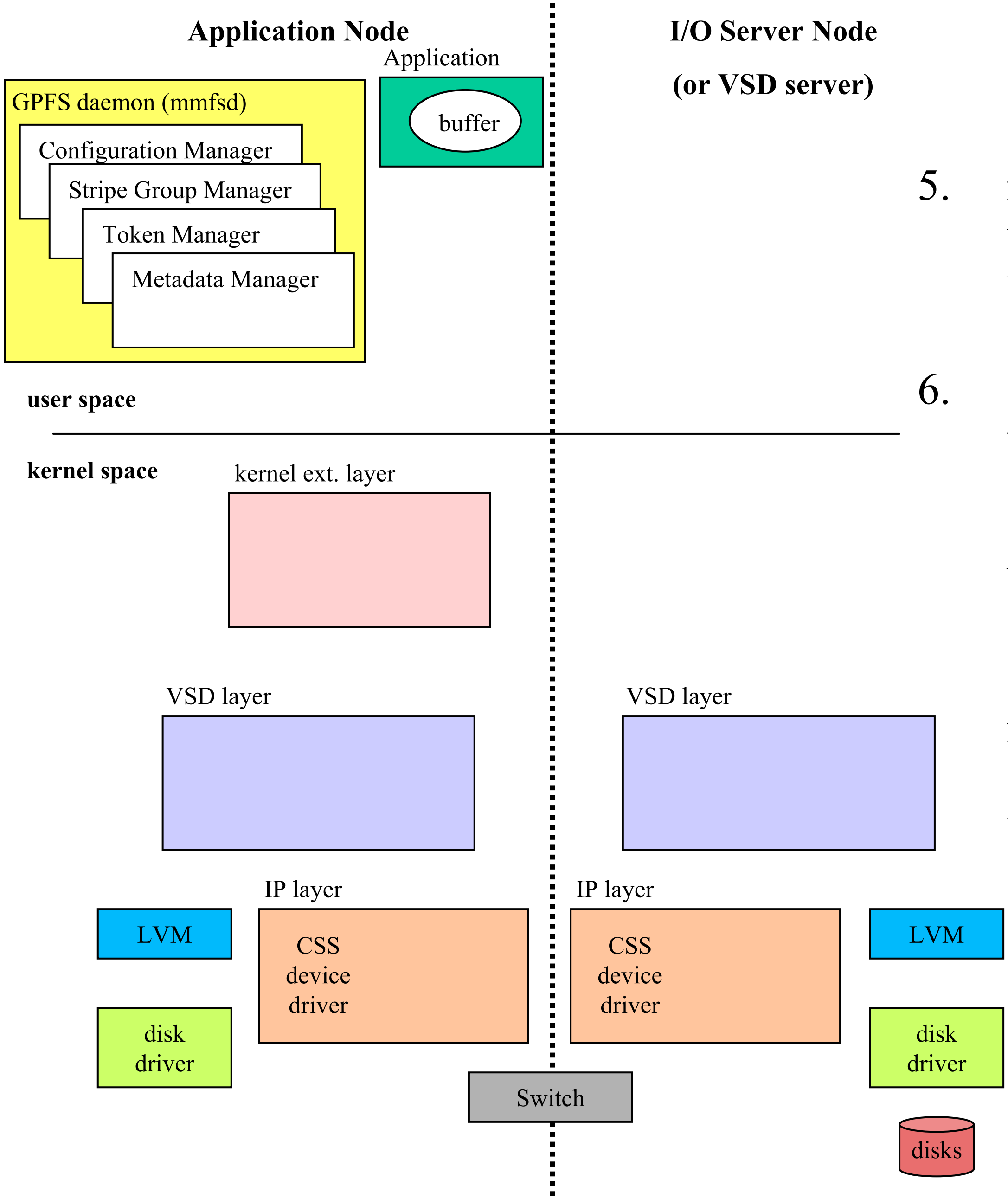
1. Application on a node makes write call with pointer to buffer in user space.

Data Flow (write)



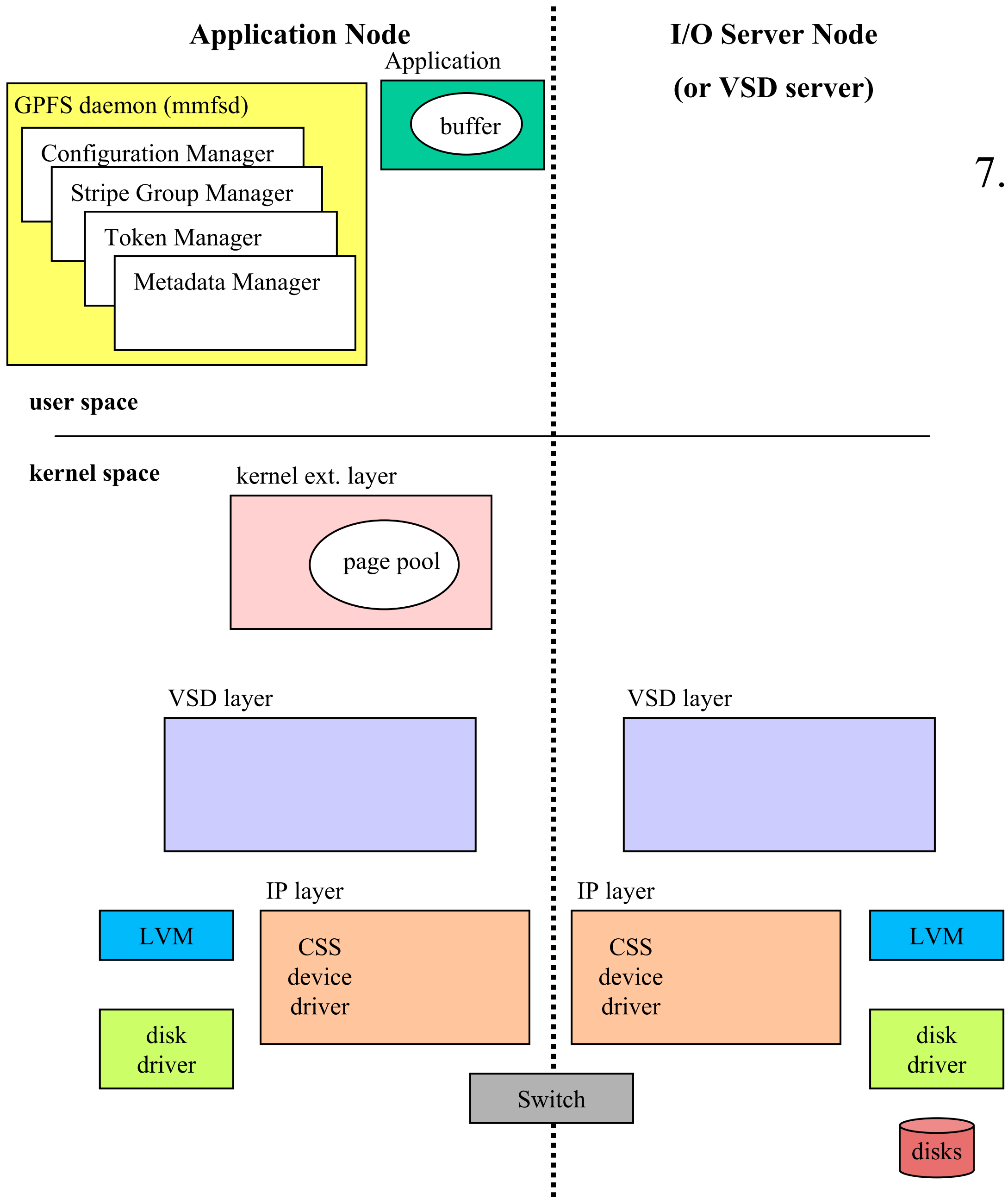
2. mmfsd daemon on application node checks for lock:
   a. if already holds write token, skips interaction with Token Manager Server (next two steps)
   b. if local file for node, write token is acquired through Token Manager, else Token Manager Server is contacted. The Token Manager Server reports a list of files holding the token so that the requesting node may contact them directly for negotiation.
3. Token Manager Server coordinates if there is a problem with the required-byte-range requested
4. mmfsd receives Token Manager Server response of token and byte-range

Data Flow (write)



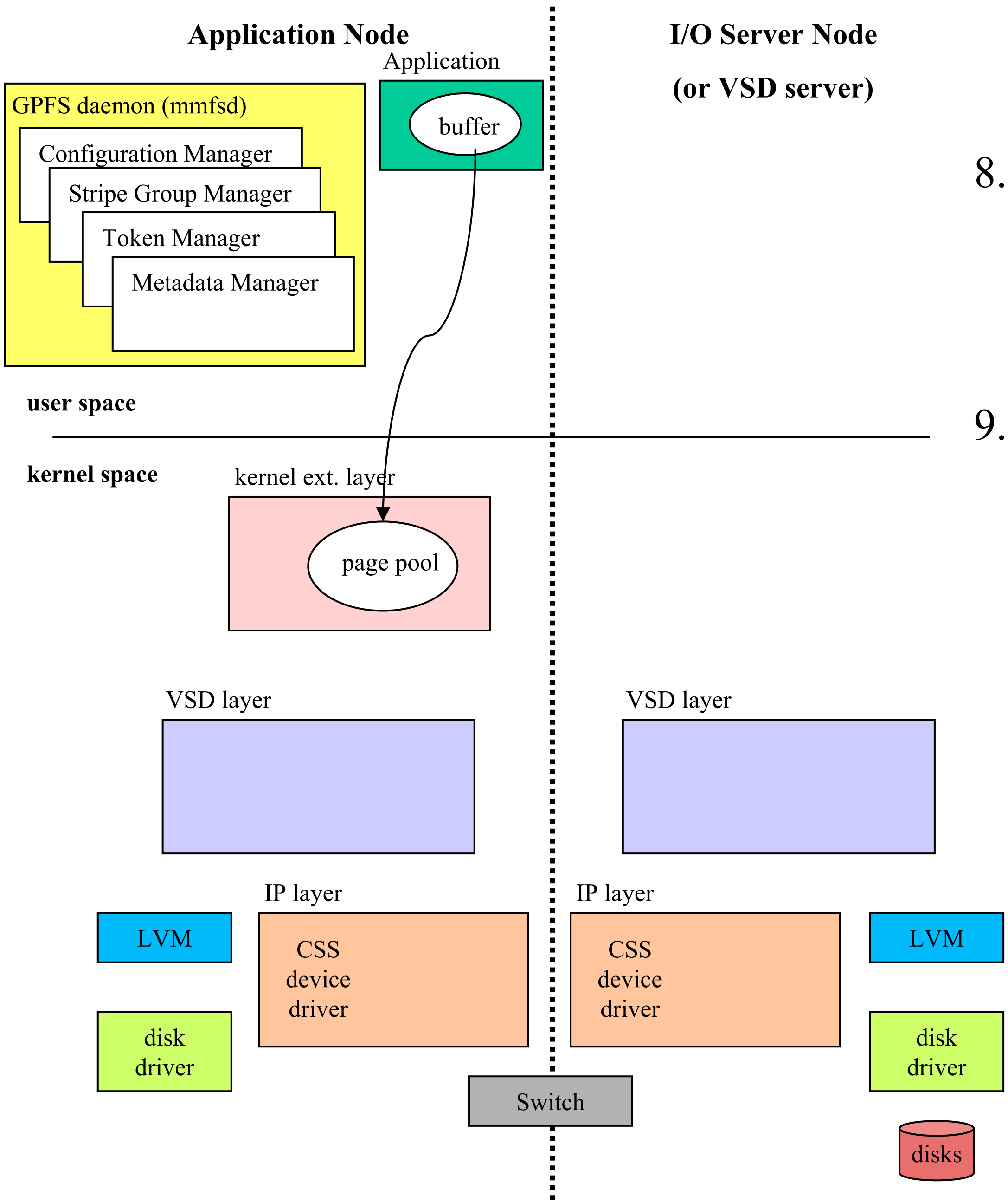
5. mmfsd gets metadata from the file's metanode and updates these metadata structures.
6. GPFS acquires disk space to write the data from the *allocation segment*, a cluster of available disk blocks. Each allocation segment contains blocks from every disk, in a round-robin order. (Two other algorithms are used when the file system grows too large.)

Data Flow (write)



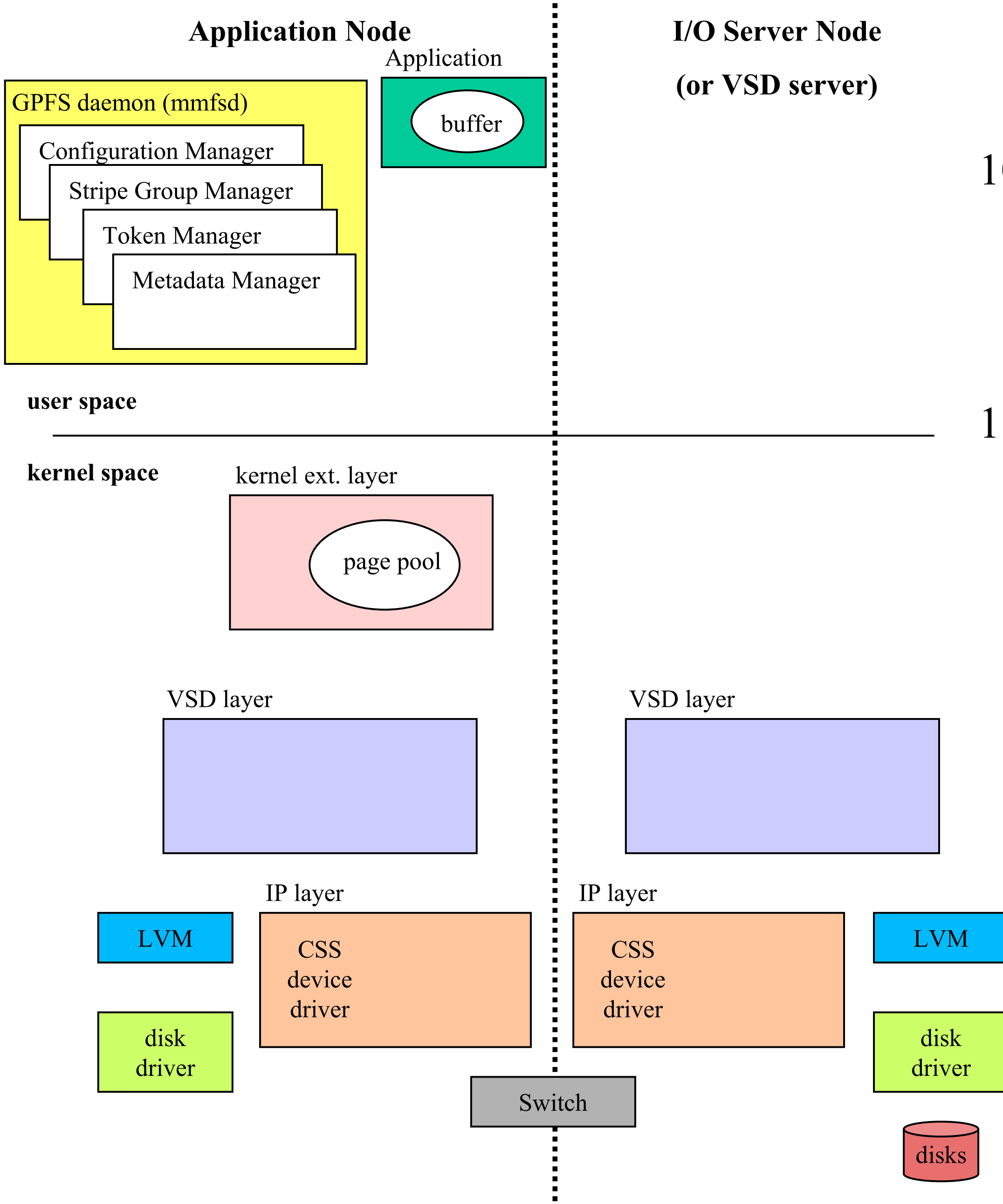
7. mmfsd acquires a buffer from the page pool, writing out the oldest dirty buffer if none available

Data Flow (write)



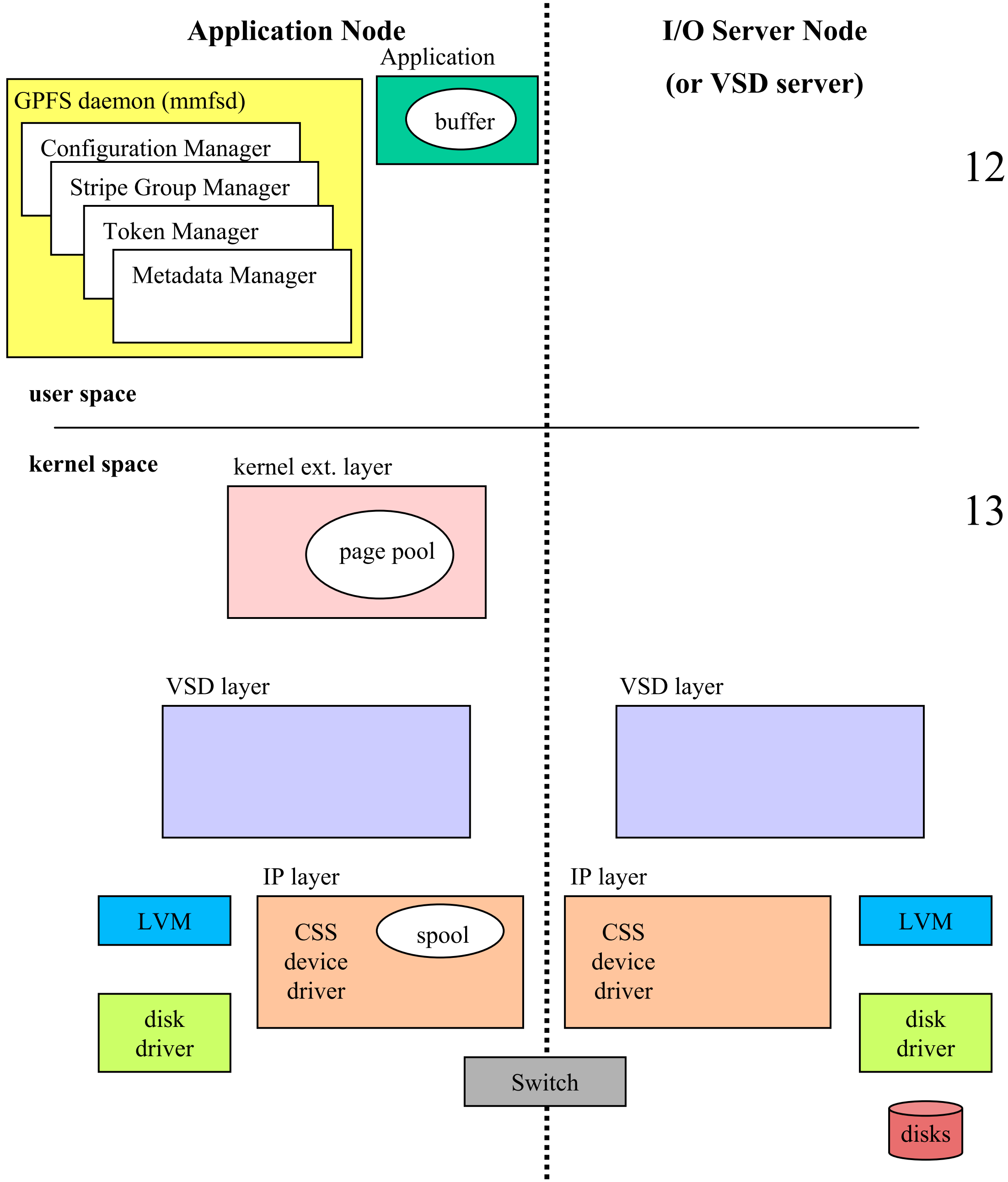
8. Data is moved from application data buffer to page pool buffer (currently 100MB) in kernel space
9. mmfsd schedules worker thread to continue the write of the data. At this point, the application has completed the write system call.

Data Flow (write)



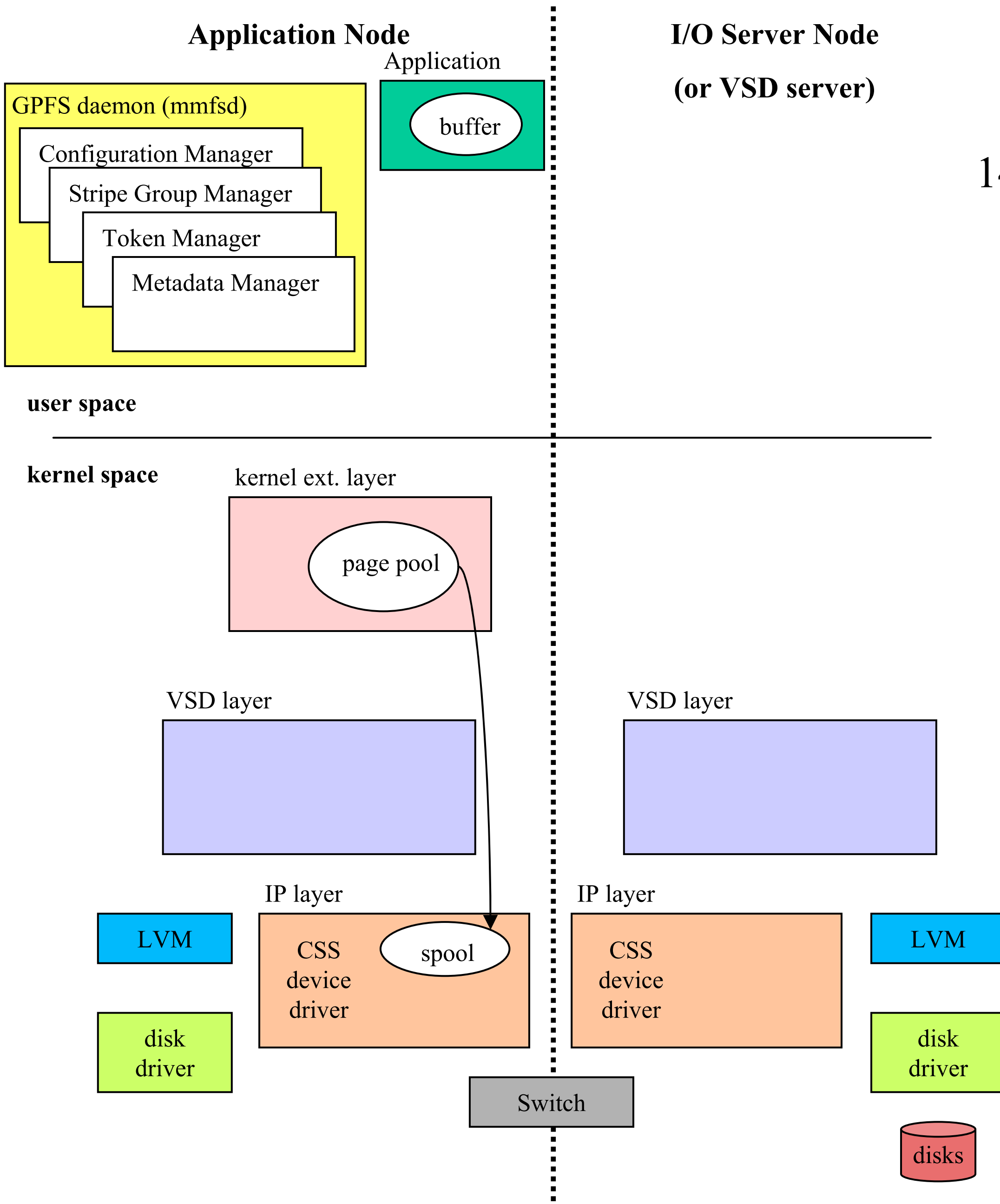
10. The GPFS thread makes a call to VSD requesting the data be written to disk in GPFS blocksize chunks.
11. The GPFS block is broken into smaller IP messages (each less than 64KB).

Data Flow (write)



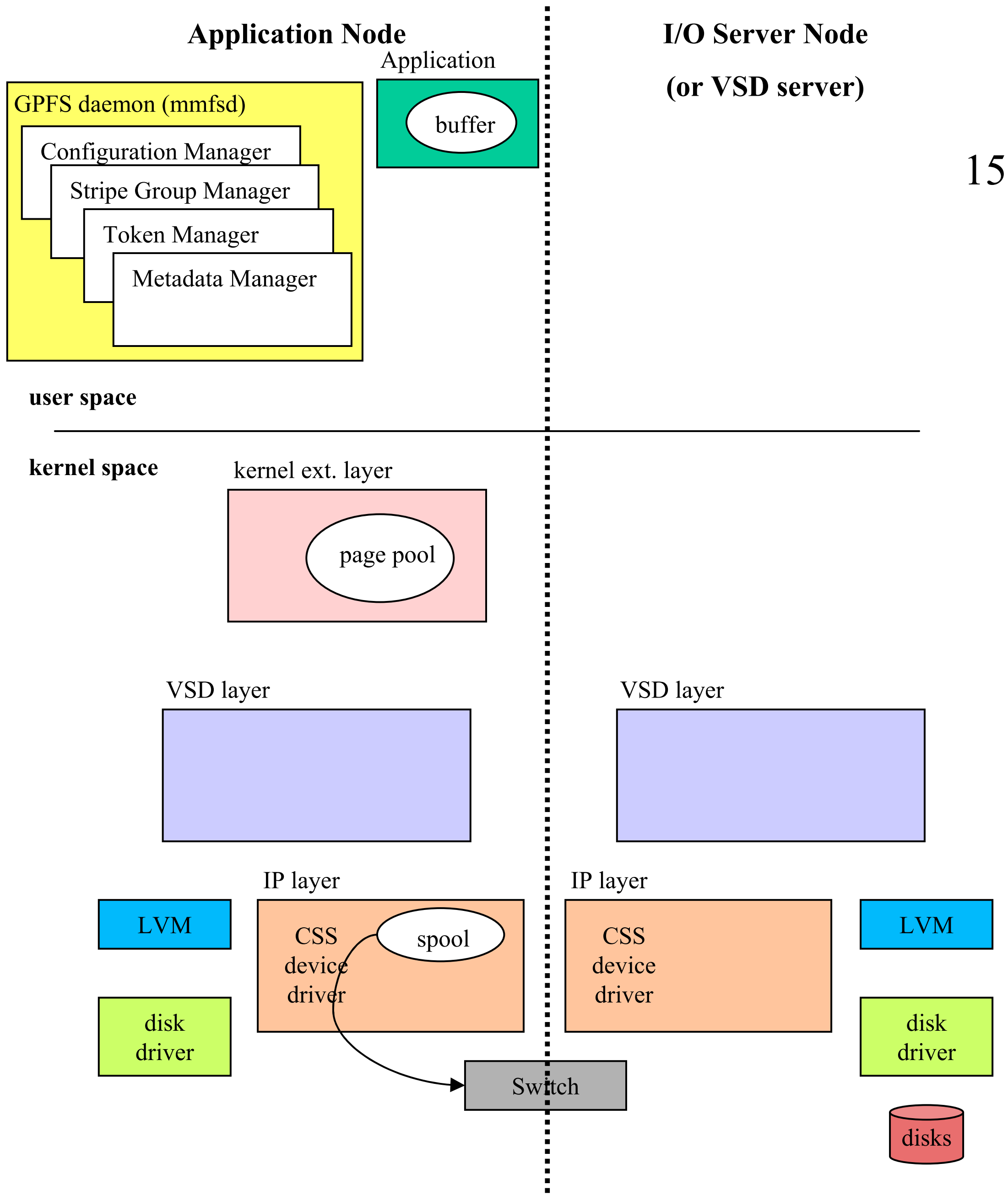
12. 256-byte mbufs (message buffers that are kernel data structures used for processing IP packets) are used to contain VSD and IP headers.
13. CSS (Communication SubSystem) allocates send pool (spool – a staging area for information to be sent over the switch) buffer equal to the data of each packet is allocated. Additional mbufs are allocated for tracking purposes.

Data Flow (write)



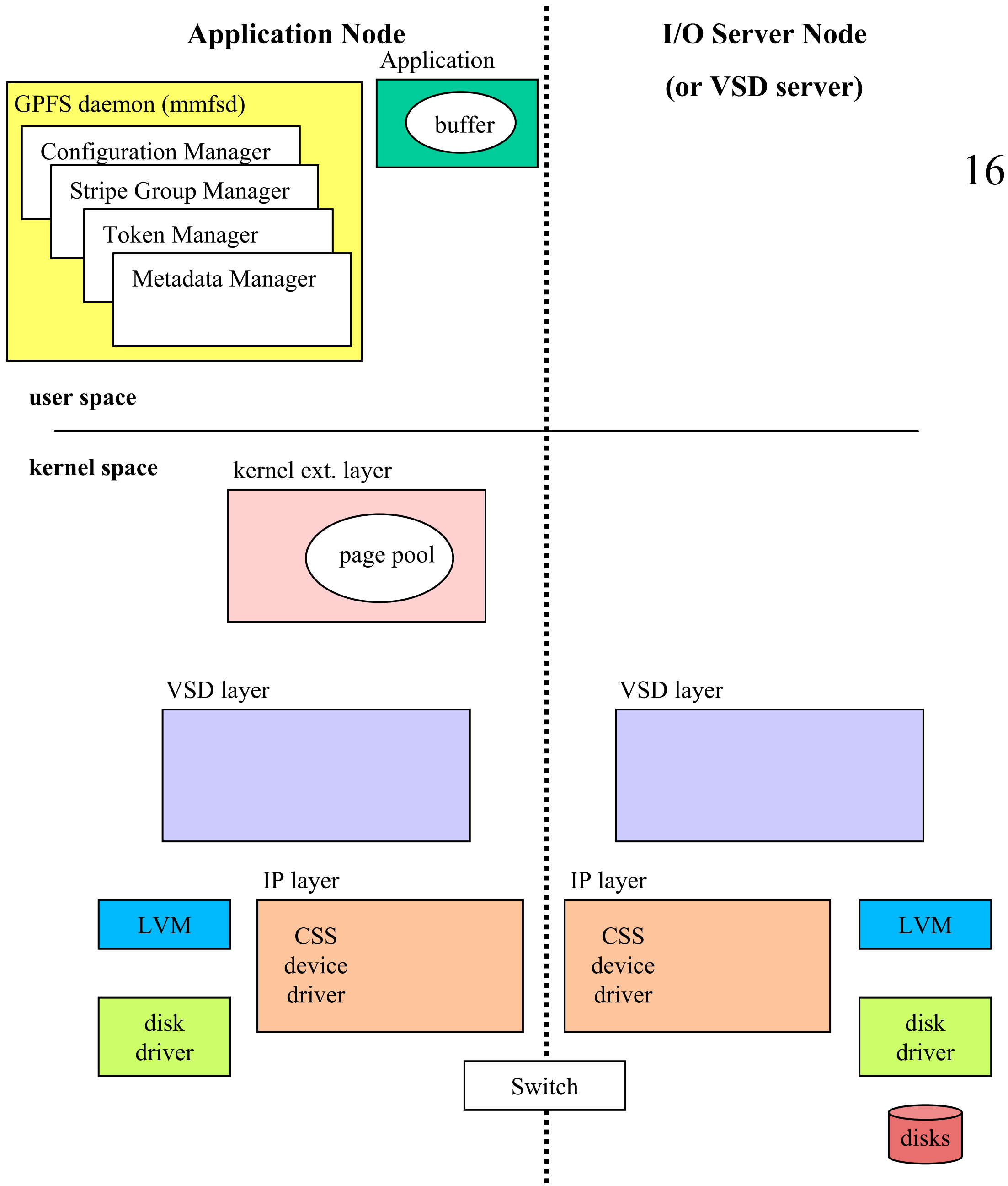
14. VSD copies data from the page pool to the send pool. (This is a second copy.)

Data Flow (write)



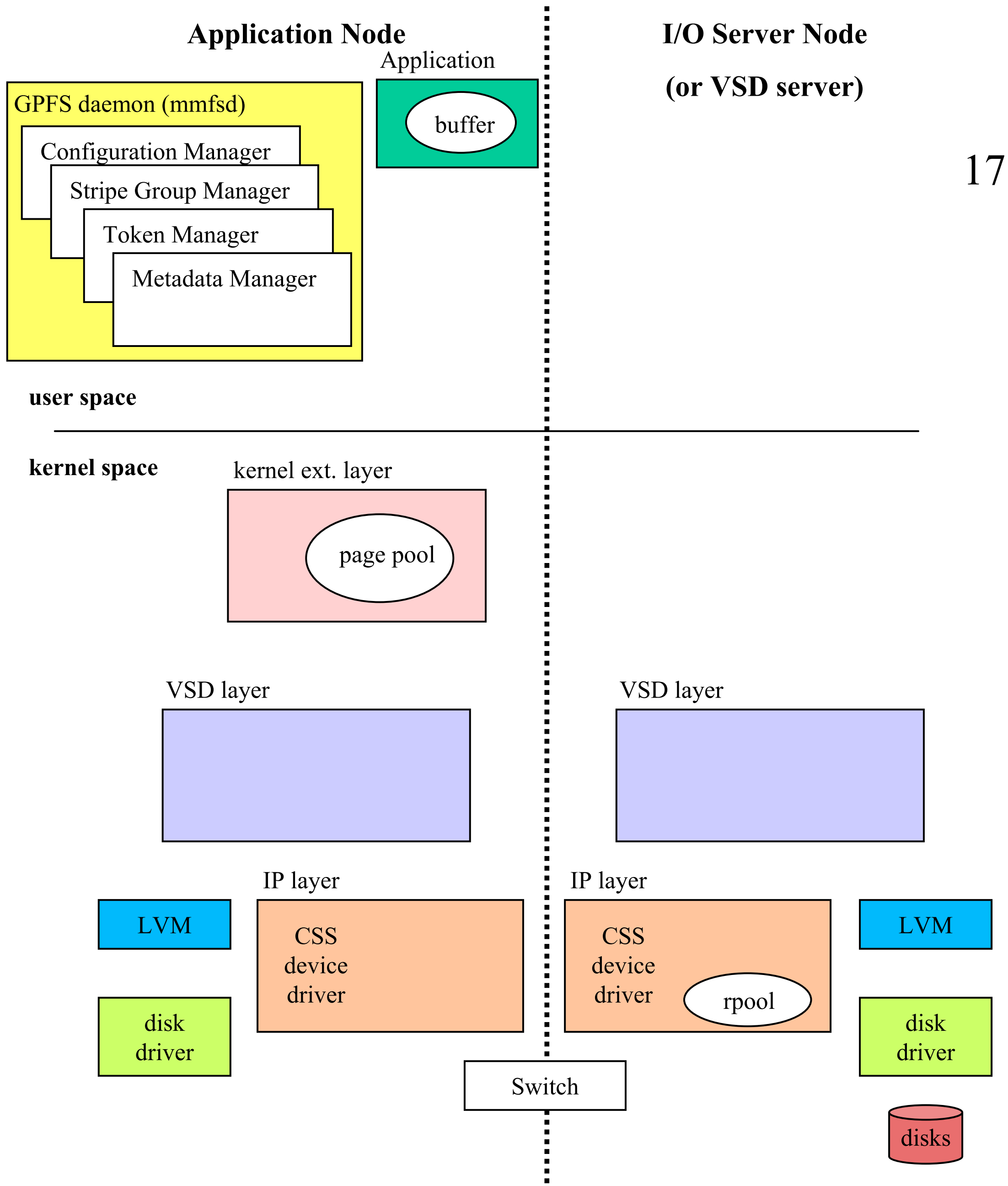
15. VSD client sends the IP packets (data) to the VSD server.

Data Flow (write)



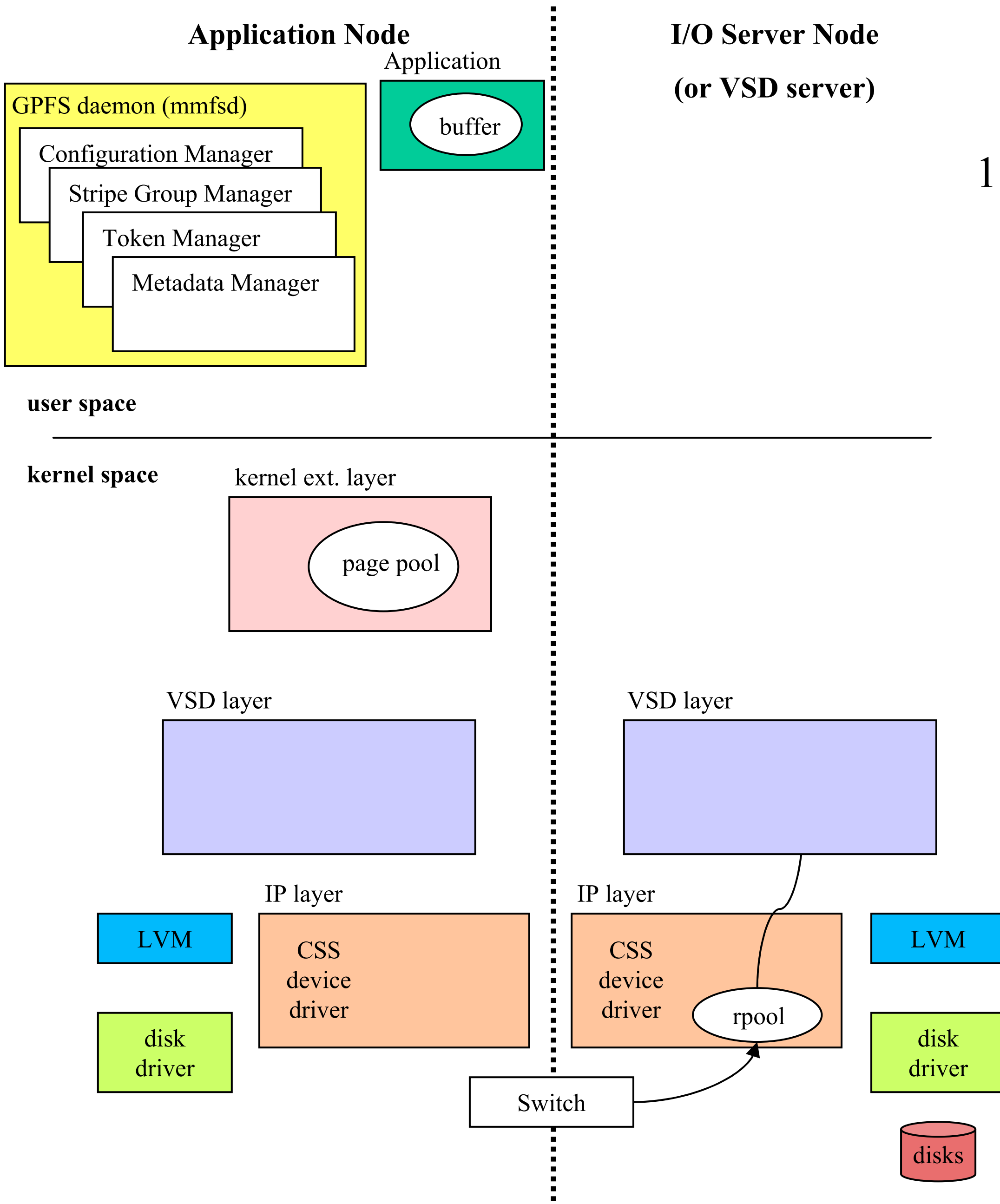
16. Once the data is transferred onto the switch, the send pool and mbufs are freed.

Data Flow (write)



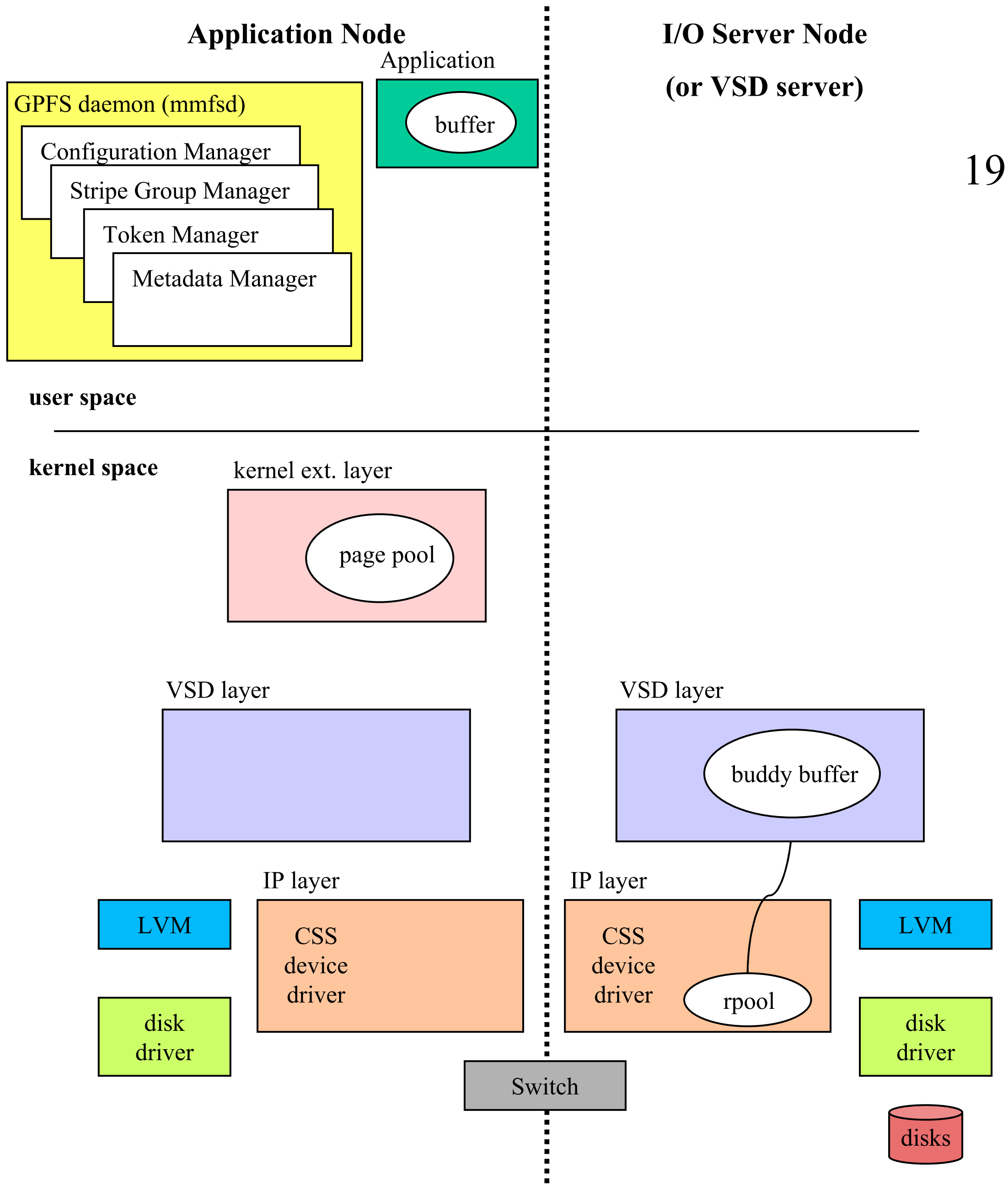
17. CSS allocates a receive buffer for each VSD packet in the request.

Data Flow (write)



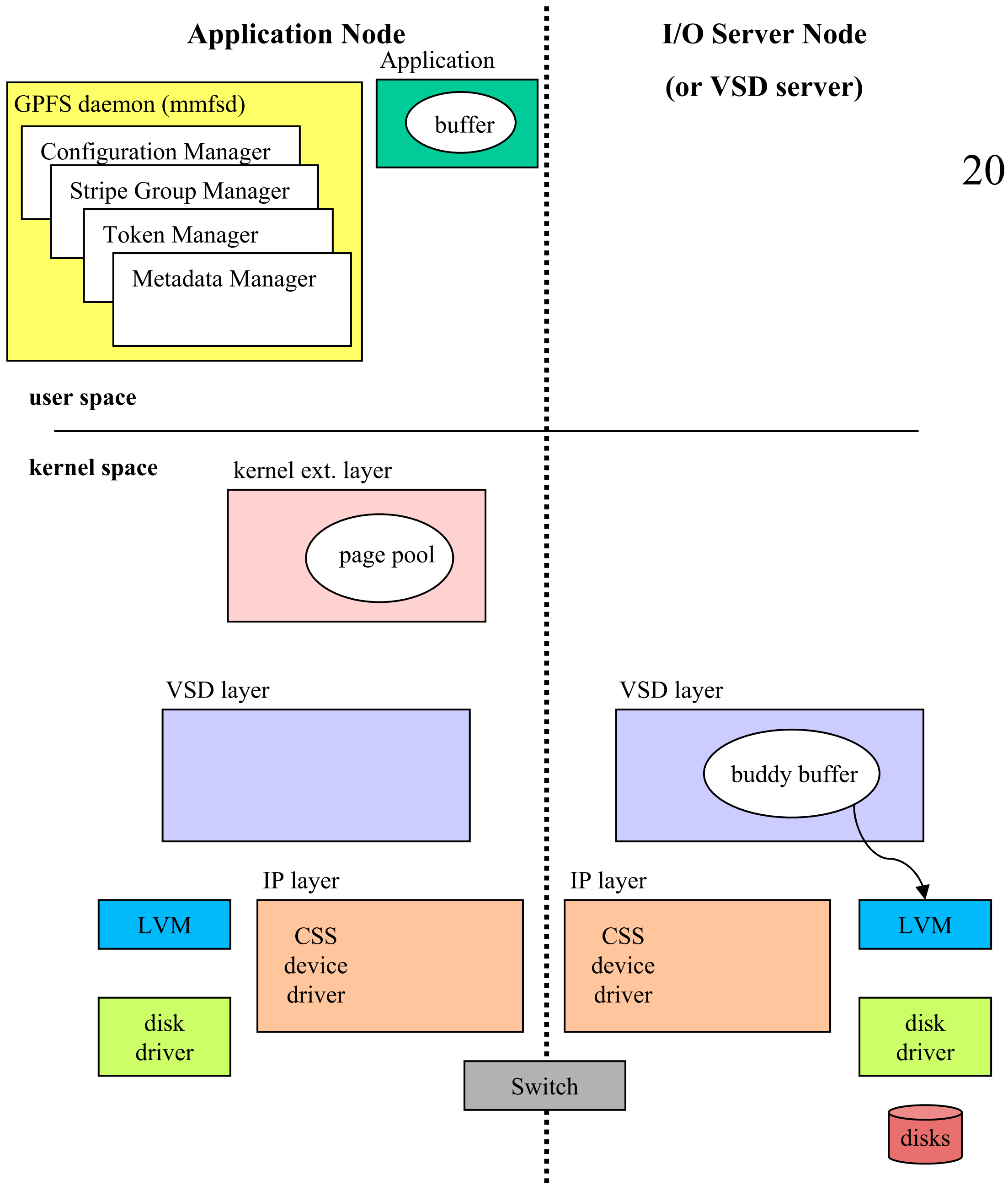
18. Upon arriving at the VSD server CSS receive pool, the data is forwarded to the VSD layer.

Data Flow (write)



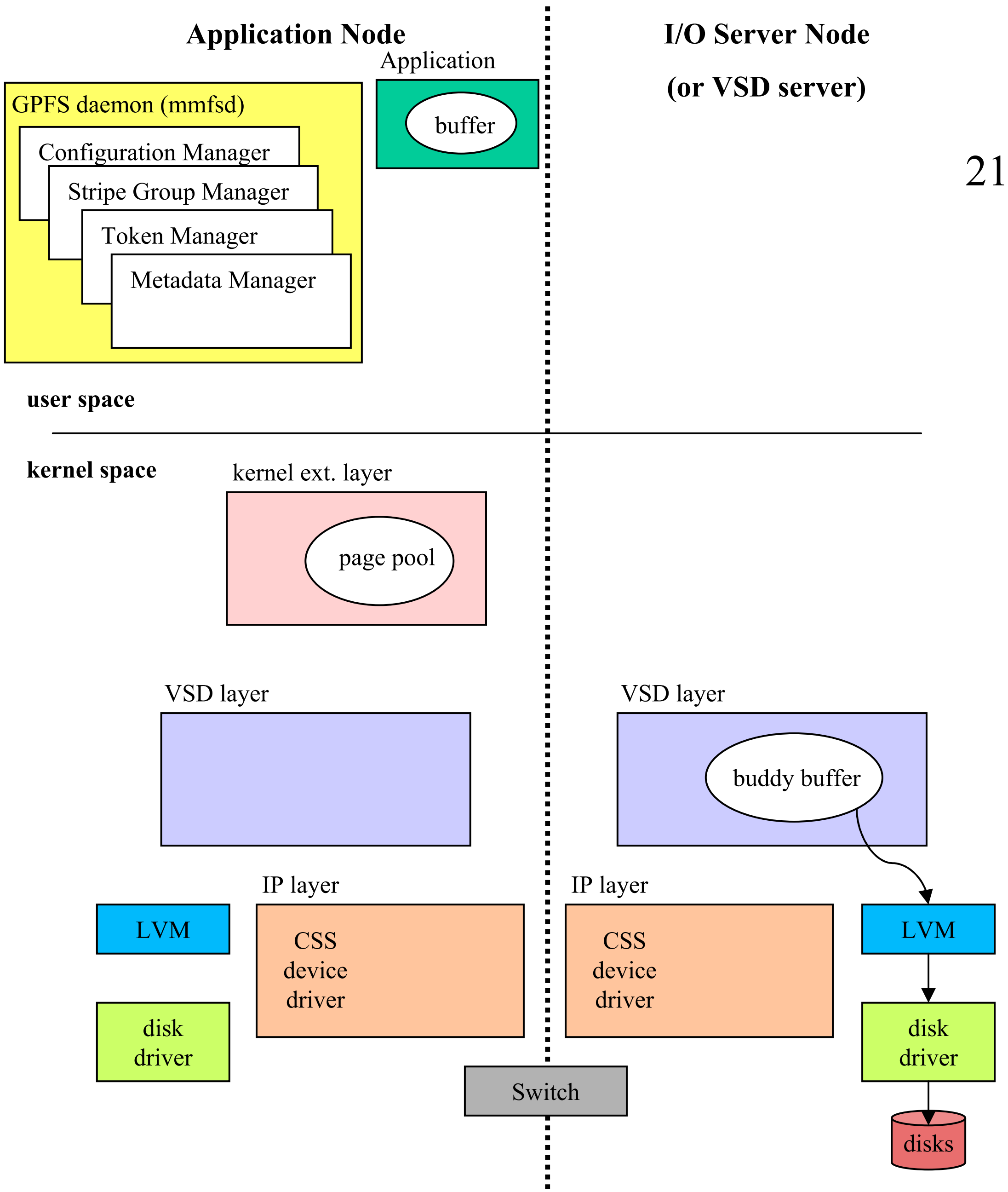
19. Once all packets in the request have been received by the VSD server, a buddy buffer is allocated to reassemble the data. If not enough space, the request is queued and the data remains in the CSS receive pool.

Data Flow (write)



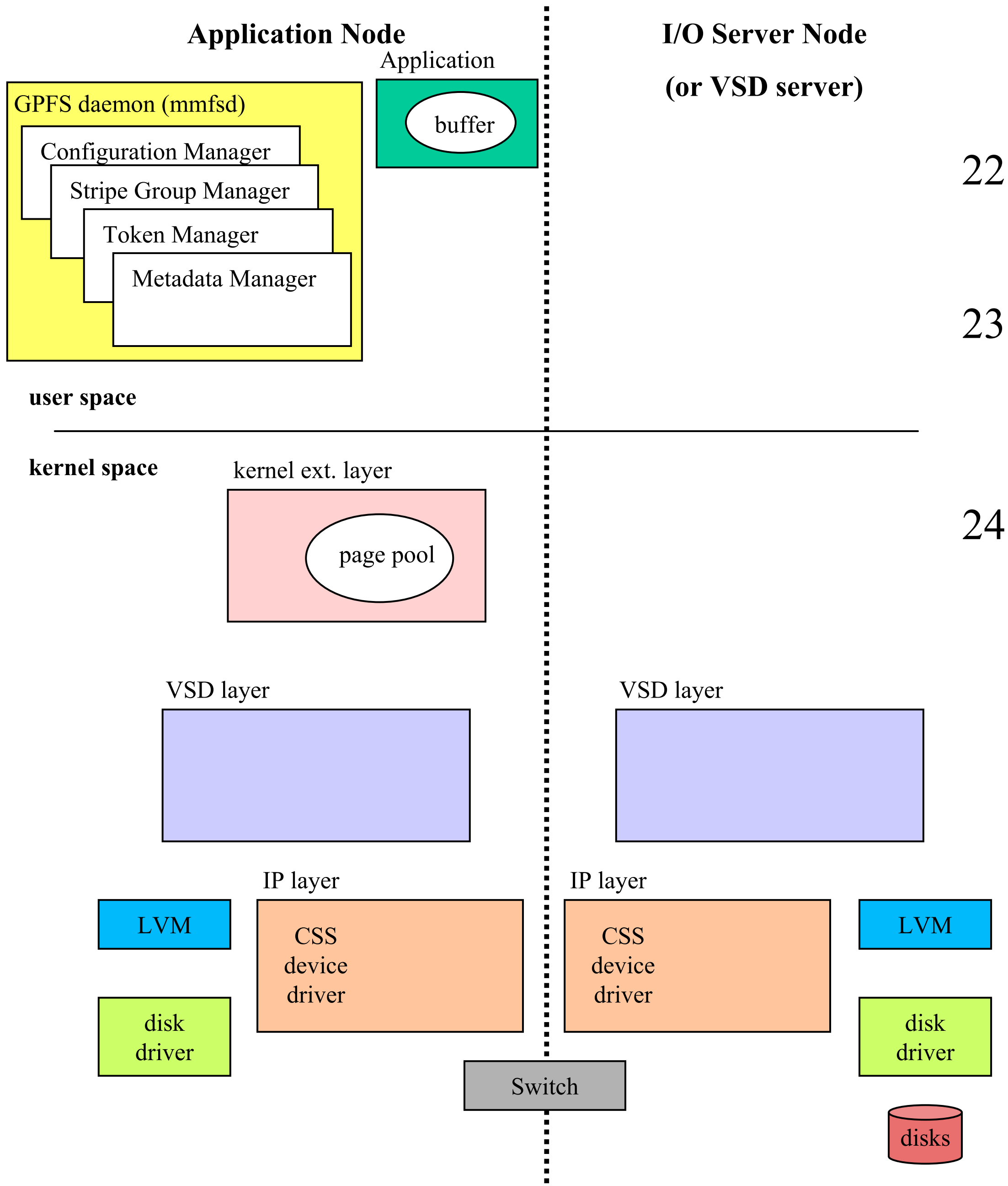
20. VSD server releases mbuf/rpool space and calls LVM (Logical Volume Manager) to schedule disk write through the device driver.

Data Flow (write)



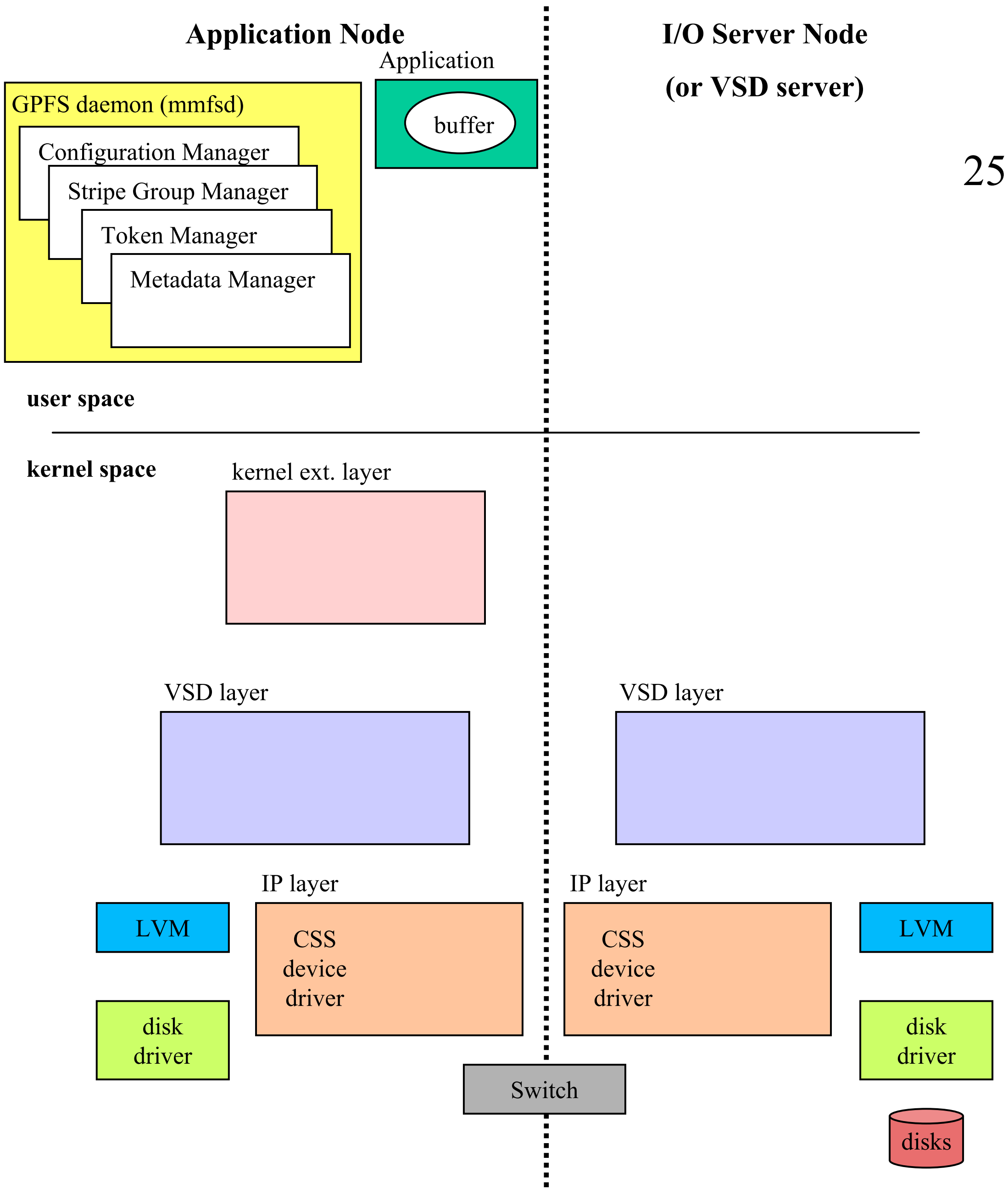
21. The device driver performs the write using 256KB blocks with DMA.

Data Flow (write)



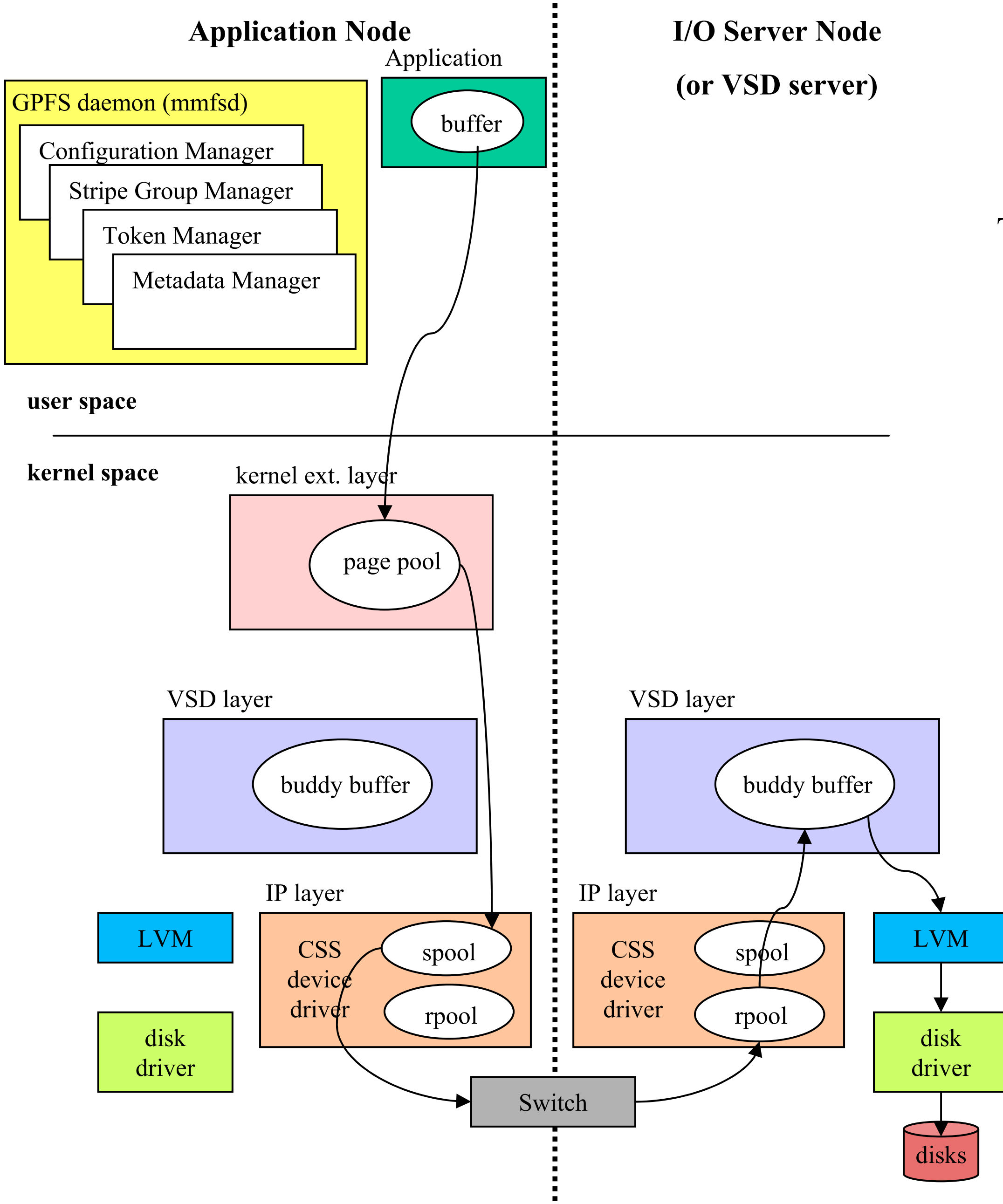
22. VSD releases buddy buffer upon completion by LVM driver.
23. VSD acquires mbuf header to send completion response to VSD client.
24. VSD client releases the request block.

Data Flow (write)



25. GPFS releases the page pool.

Data Flow (write) – Entire flow



The **READ FLOW** is similar, but in reverse. One particular issue that is different, however, is checking whether the required data is already in cache. Also, the token management is slightly different, though still preserving the consistency of the data. Again, it is the Token Manager Server that determines and resolves conflicts for a read token.

Additional Information

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